MERCURY IN THE EFFLUENTS FROM CHLOR-ALKALI PLANTS: FIRST SURVEY AT DRYDEN, JULY, 1975

August, 1975

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Ministry of the Environment

Ontario

The Honourable
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Minister

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MERCURY IN THE EFFLUENTS FROM
CHLOR-ALKALI PLANTS:
FIRST SURVEY AT DRYDEN, JULY, 1975

Inorganic Trace Contaminants Section②
Laboratory Services Branch①

August, 1975

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This survey was carried out by
Raymond McVicars and Bernard Neary. The mercury
analyses were done by Raymond McVicars and
Darryl Russell. The data were compiled and the
report prepared by Bernard Neary

AN INTENSIVE SURVEY OF MERCURY
IN THE EFFLUENT FROM THE DRYDEN CHEMICALS
AND THE REED PAPER PLANTS
IN DRYDEN, ONTARIO,
JULY 21-25, 1975

INTRODUCTION

Dryden Chemicals, Limited, operates a mercury cathode chlor-alkali plant in Dryden, Ontario, and according to company records, produces approximately 34 tons of chlorine per day. The plant is situated in close proximity to Reed Paper Limited (Dryden Division), a kraft pulp and paper mill that is the prime consumer of the chlorine and caustic produced by Dryden Chemicals. The water used in the chlor-alkali plant is taken from the Wabigoon River, approximately one mile downstream from Lake Wabigoon, and the waste water is carried by sewers through the paper mill. The mixed chlor-alkali/kraft mill wastes then flow directly into the Wabigoon River (see Figures 1 and 2).

From 1962 to 1970, Dryden Chemicals released wastes containing mercury without treatment, and this has resulted in the contamination of sediment and fish downstream of the plant. In March, 1970, a control order from the Ontario Water Resources Commission was issued directing Dryden Chemicals to conduct in-plant modifications for waste water recycling, and for treatment of mercury contaminated wastes.

The present facilities for treating wastes containing mercury consist of two settling tanks (capacity 60,000 and 90,000 gallons) into which mercury contaminated water is diverted.

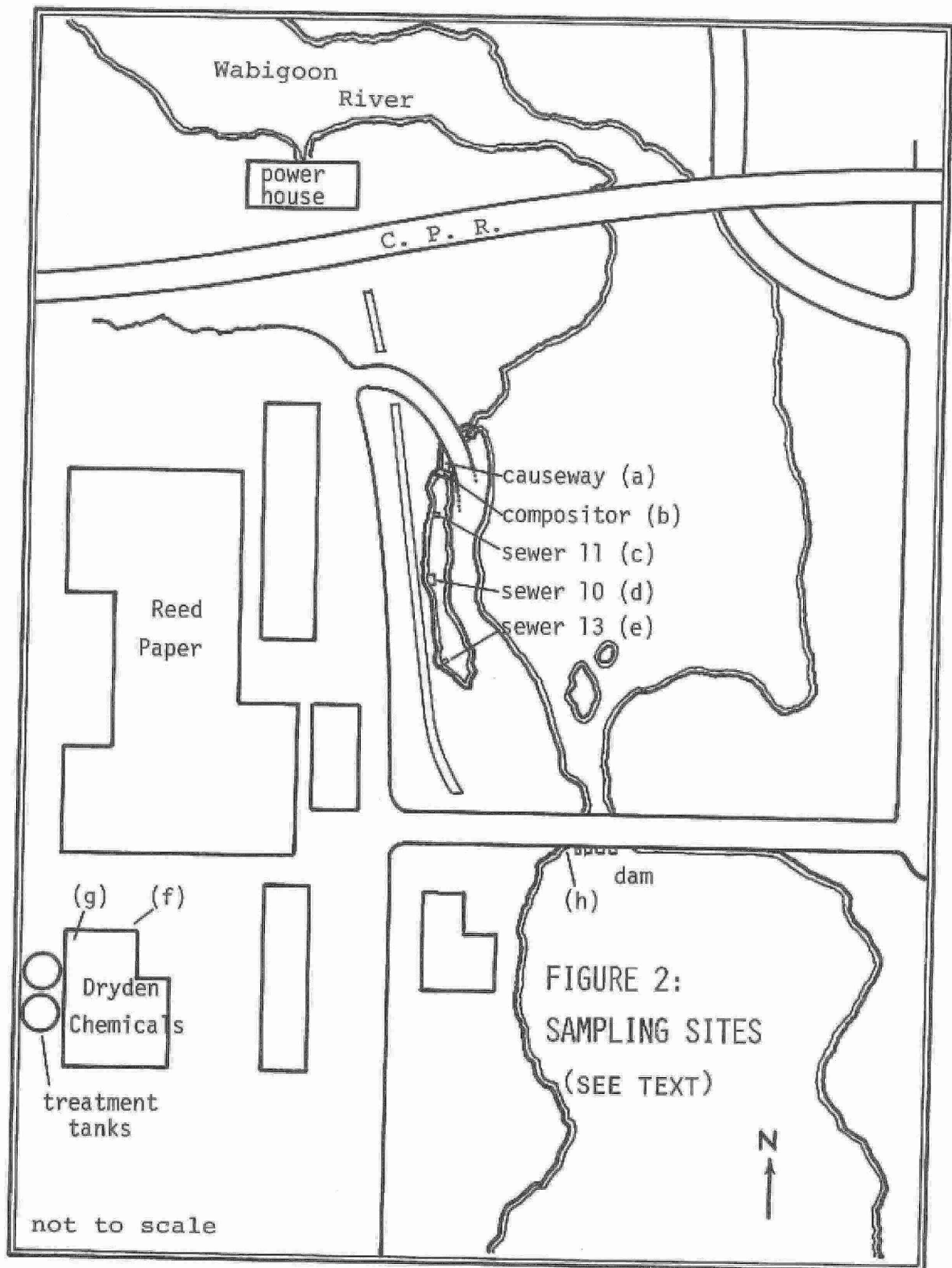The treatment consists of agitation and pH adjustment

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FIGURE 1: LOWER WABIGOON SYSTEM

Clay Lake

Rugby Lake

Gullwing Lake

Wabigoon River

Town of
Dryden

Dryden Chemicals

Wabigoon Lake

1 inch = 4 miles

Eagle
Lake

of the waste in the tank, the addition of 400 to 700 pounds of sodium sulfide, and followed by thiosulfate. The resulting mercuric sulfide is co-precipitated with iron added as ferric chloride, and settling is allowed over 3-4 days. The tank is emptied without filtration through pipes (at the 5 foot level in the 60,000 gallon tank and at the 6 foot level in the 90,000 gallon tank) into the treatment tank drain. This treated waste is combined with uncontaminated water used to cool the chlor-alkali cells, and some kraft mill effluents, and emerges in the causeway in sewer 13 (see Figure 2). The accumulated precipitate at the bottom of the settling tanks is removed when necessary (about once a year), mixed with concrete, and buried in a special disposal site in a pit lined with polyethylene.

Arising from the stipulations contained in the 1970 control order, Dryden Chemicals Limited is required to maintain records of all mercury discharges emanating from the plant. The mercury discharges are also independently monitored by the Ontario Ministry of the Environment.

In November, 1975, the chlor-alkali plant plans to convert from a mercury cathode process to a permionic membrane process which does not require the use of mercury. In order to provide an up-dated record of all possible sources of mercury discharges from the chlor-alkali and the paper plants prior to the changeover, an intensive survey was carried out during the period July 18-25, 1975. During this time, a laboratory equipped to perform mercury analyses was set up in the Town of Dryden sewage treatment plant.

Wabigoon
River

power
house

C. P. R.

causeway (a)
compositor (b)
sewer 11 (c)
sewer 10 (d)
sewer 13 (e)

Reed
Paper

dam
(h)

(g)   (f)

Dryden
Chemicals

treatment
tanks

FIGURE 2:
SAMPLING SITES
(SEE TEXT)

N

not to scale

In conjunction with the survey, analytical quality control studies were carried out on:

(1) The effects of preserving samples for mercury analysis.

(2) The differences, if any, between in-situ analyses and results obtained at the Toronto central laboratory.

(3) Variations of results obtained on a series of samples submitted to the Freshwater Institute laboratory in Winnipeg for independent confirmation of analyses.

All of the data and comments pertaining to the analytical control aspects of the survey are contained in the second section of the report.

SAMPLING

Samples for mercury analysis were taken in 32 oz. boro-
silicate glass bottles to which potassium permanganate
and nitric acid had been added as preservatives. The
samples were analyzed in Dryden, usually within twelve
hours of sampling, and the same samples were shipped air
express to the Toronto laboratories, where analyses
were also carried out, within six days of sampling.
Portions of eight samples were shipped to the Freshwater
Institute in Winnipeg, Manitoba, after analysis in Dryden,
for independent confirmation of the results.

The points at which samples were taken are shown on
Figure 2 and are described below:

a) Causeway:

The causeway is an open ditch about 150 yards long
into which all of the discharges from both Dryden
Chemicals and Reed Paper emerge. This total effluent
was sampled as it entered a small lagoon prior to
its confluence with the Wabigoon River.

b) 24 Hour Causeway Composite:

These samples were taken from a metal bucket in a
small shed in which a mechanical compositor takes
a sample of the causeway every 1.5 minutes, and empties
it into the bucket. Composite samples were on a 0600
to 0600 basis, and were provided to the Ministry of
the Environment analysts by the paper mill staff.

Occasional grab samples were taken from the compositing bucket.

c) Sewer 11:

This is the most northerly input into causeway, and includes discharges from the bleaching and dyeing operations in the paper mill. Samples were taken directly from the mouth of the pipe.

d) Sewer 10:

This sewer, which is comprised of three pipes, contains most of the water flow from the paper mill, and is the major input to the causeway. Direct access to the pipes was not possible, but the flow was sufficient to allow sampling from the other side of the causeway in the direct flow from these pipes. One sample was also taken from the sewer 10 compositor which is located inside the paper mill.

e) Sewer 13:

This is the most southerly input into the causeway, and includes wastes from both the paper mill and the chlor-alkali plant. Direct access to the mouth of the sewer was difficult, and most samples were taken approximately 3 feet from the mouth of the discharge pipe. Sewer 13 has a compositor, and two samples were taken from this compositing bucket.

f) East and West Uncontaminated Lines:

These are two pipes in the chlor-alkali plant containing cooling water for the electrochemical cells. Sampling

was done from small taps on the pipes. This cooling
water does not come into direct contact with the
mercury and the east line is discharged without
treatment, while the west line is recycled as cooling
water.

g) Treatment Tank Drain:

This is the pipe through which the contents of the
settling tanks are emptied. The sampling point was
a small tap on the pipe inside the chlor-alkali plant.
During the discharge of the treated water, a small
continuous flow through this tap collects in a bucket,
from which several grab samples were also taken.

h) Wabigoon River:

Samples were taken above the dam that diverts most
of the Wabigoon River into the mill. There were also
samples taken in Lake Wabigoon, and about one mile
downstream of the mill, at the Town of Dryden sewage
treatment plant.

ANALYSIS

The method of analysis for mercury has been described
in detail elsewhere (J. N. Bishop, et al., The Determination
of Mercury in Environmental Samples, M.O.E. Report,
January, 1973). The sample is digested with nitric acid,
sulfuric acid, potassium permanganate, and potassium
persulfate for two hours at 80°C to ensure breakdown of
organic materials and to convert all the mercury present
to the divalent ion. After cooling, the excess potassium
permanganate is reduced with hydroxylamine sulfate, then
the mercury is reduced to its elemental state with stannous
sulfate. The sample is then aerated, and the resulting
stream of air and volatilized mercury is passed through
an ultraviolet absorption cell, where the absorption at
253.7 nm is recorded. The absorption is proportional to
the mercury concentration of the sample. The limit of
detection by this method is approximately 0.05 ug/l (ppb).

The same method of analysis was used both at the Toronto
and Dryden laboratories. Agreement between the results
of the two laboratories was very good, and the details
of this comparison of the two sets of results appear in
the second section of this report. The accuracy of the
analyses was checked by the analysis of the National
Bureau of Standards mercury solution (SRM # 1642, 1.18 ug/l)
with each run of samples.

RESULTS

The results have been divided into time periods reflecting the batch treatment discharge cycle at the chlor-alkali plant.

July 18-20:

From July 18 to July 20, inclusive, a period in which there was no scheduled discharge of treated mercury wastes, the concentration of mercury in the causeway ranged from 0.3 to 2.8 ug/l, based on ten grab samples. On July 20, a steady increase in mercury concentration from the 0.3 to 0.5 ug/l range of July 18 and 19 to 2.8 ug/l was noticed, but there was no apparent cause for this fluctuation.

July 21:

On July 21, the contents of the 60,000 gallon settling tank were released starting at 1015 and lasting about 4.5 hours. The concentration of mercury in the causeway 45 minutes before the discharge commenced was 1.8 ug/l, and during the course of the discharge, the concentration ranged from 1.0 ug/l to 2.9 ug/l, and remained below 2.0 ug/l after the discharge. The concentration of mercury in the treatment tank drain ranged from 17 to 210 ug/l, and that of sewer 13 ranged from 2.6 to 4.1 ug/l. These levels are plotted against time in Figure 3, and are listed in Table 1.

July 22-24:

During this period, the concentration of mercury in the causeway remained quite low, ranging from 0.2 to 1.4 ug/l, based on 12 grab samples.

FIGURE 3: FIRST BATCH DISCHARGE (JULY 21)

causeway (left hand scale)

sewer 13 (left hand scale)

treatment tank drain
(right hand scale)

Mercury (ug/1)

Mercury (ug/1)

TIME

-11-
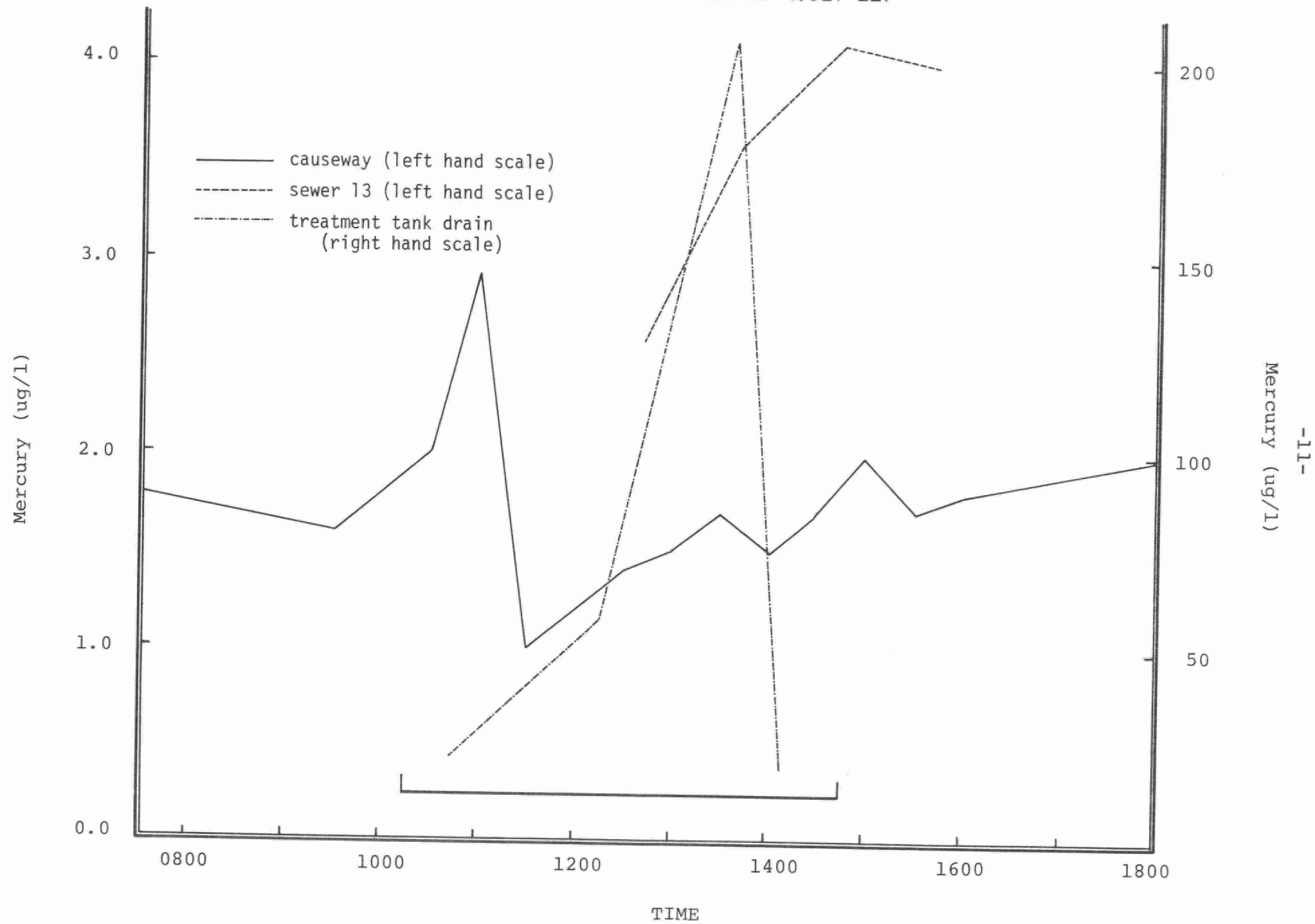
TABLE I

FIRST BATCH DISCHARGE, JULY 21, 1975

TIME	MERCURY CONCENTRATION (ug/l)		
	CAUSEWAY	TREATMENT TANK DRAIN	SEWER 13
0730	1.8		
0930	1.6		
1030	2.0		
1045		23	
1100	2.9		
1130	1.0		
1200	1.2		
1215		56	
1230	1.4		
1240			2.6
1300	1.5		
1315		210	
1330	1.7		
1340			3.6
1400	1.5		
1415		17	
1430	1.7		
1440			4.1
1500	2.0		
1530	1.7		
1540			4.0
1600	1.8		
1800	2.0		
2045	0.9		
2200	1.1		

July 25:

The contents of the 90,000 gallon settling tank were discharged over a period of about 3.5 hours starting at 0805. Prior to the start of this discharge, the concentration of mercury in the causeway was 0.2 ug/l. Over the next five hours, the concentration ranged from 0.4 to 16 ug/l, except for one grab sample from the causeway which had a mercury level of 1,500 ug/l. The concentration of mercury in the treatment tank drain ranged from 37 to 400 ug/l, while that of sewer 13 increased from 0.4 ug/l prior to the discharge, to 5.4 ug/l. Sewers 10 and 11 were also monitored, with ranges of 0.2 to 1.7 ug/l and 0.1 to 0.2 ug/l, respectively.

The concentration of mercury in the causeway, the treatment tank drain, and sewer 13 are plotted against time in Figure 4, and listed in Table 2. The concentration of mercury in the causeway over the entire study period of July 18 to July 25 is shown in Figure 5.

FIGURE 4: SECOND BATCH DISCHARGE (JULY 25)

causeway (left hand scale)

sewer 13 (left hand scale)

treatment tank drain
(right hand scale)

Mercury (ug/1)

Mercury (ug/1)

TIME

-14-
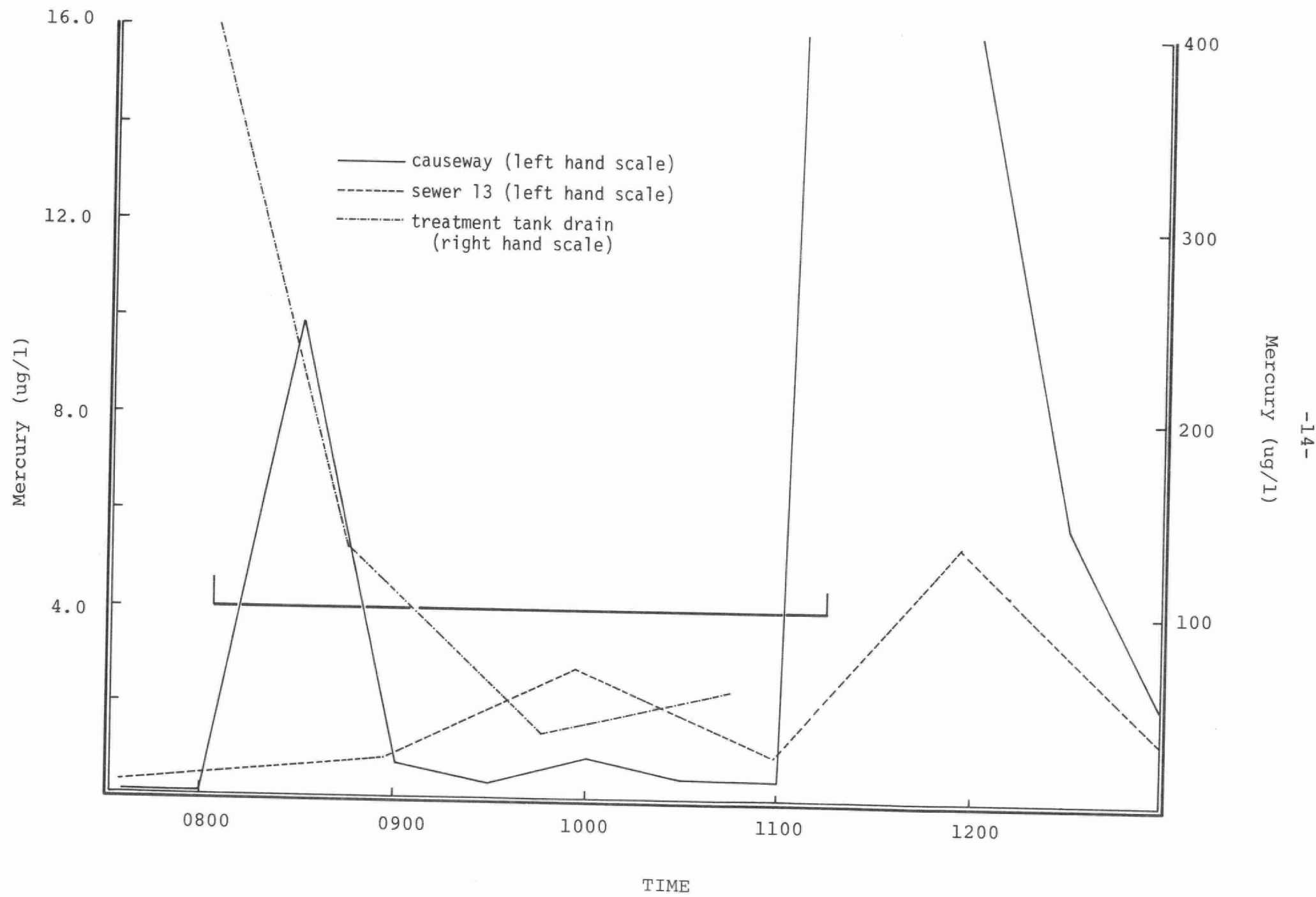
TABLE 2

SECOND BATCH DISCHARGE, JULY 25, 1975

	MERCURY CONCENTRATION (ug/l)		
TIME	CAUSEWAY	TREATMENT TANK DRAIN	SEWER 13
0730	0.2		
0740			0.4
0800	0.2		
0805		400	
0830	9.8		
0845		130	
0855			0.9
0900	0.8		
0930	0.4		
0945		37	
0955			2.8
1000	0.9		
1030	0.5		
1045		54	
1055			1.0
1100	0.5		
1130	1500		
1155			5.4
1200	16		
1230	5.8		
1255			1.5
1300	2.0		

FIGURE 5: MERCURY IN CAUSEWAY

1st discharge

2nd discharge

-16-
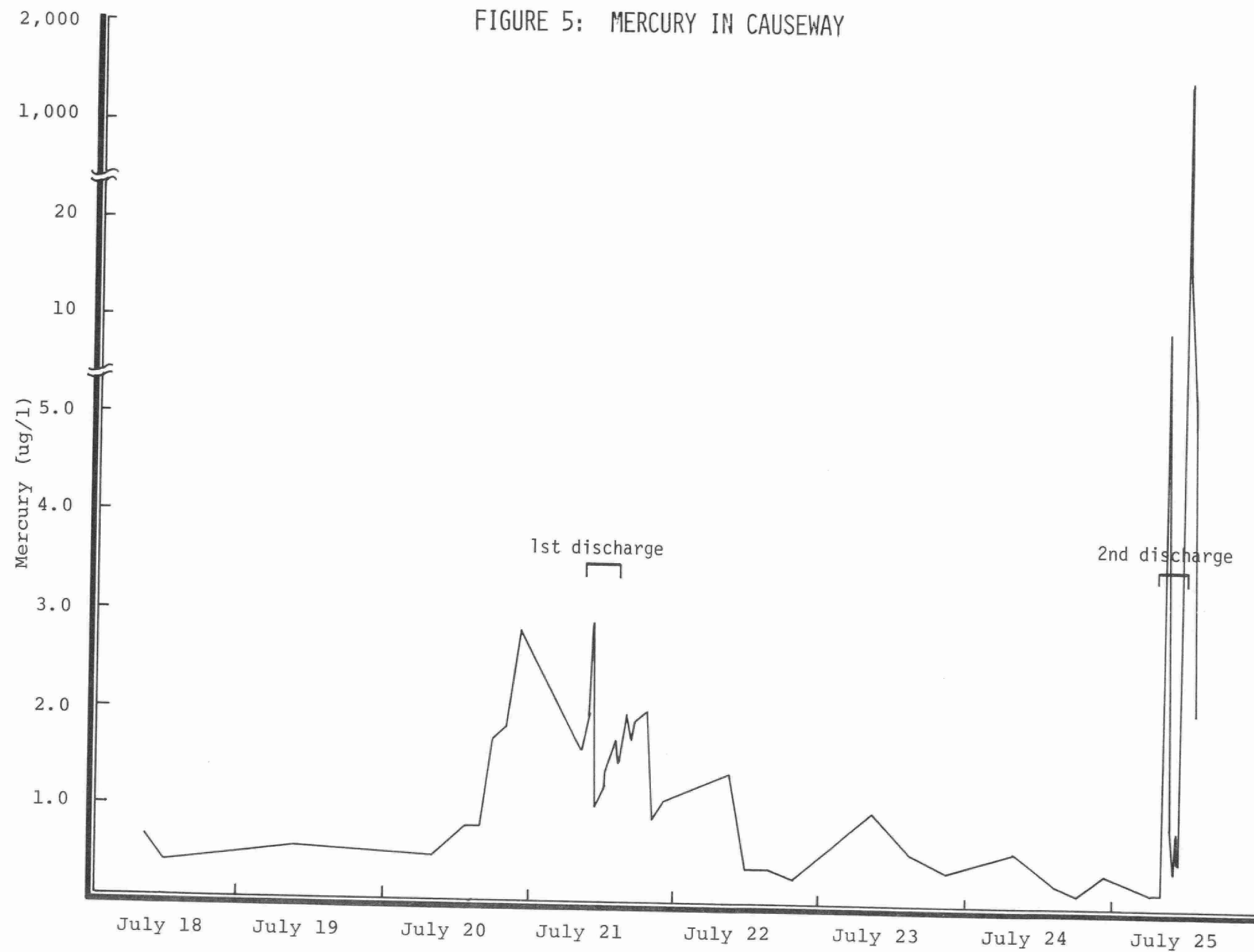
DISCUSSION

The most notable feature of the results obtained in this
survey is the large fluctuation in mercury concentration
both in the treatment tank drain and in the causeway.
During the first batch discharge, the concentration of
mercury in the treatment tank drain varied by a factor
of nine, and that in the causeway by a factor of three.
The second batch discharge resulted in variations in the
concentration of mercury in the treatment tank drain of
a factor of eleven, and in the causeway, the concentration
varied by a factor of eighty (neglecting the result of
1,500 ug/l).

The average batch discharge (using figures reported by
Dryden Chemicals) is about 50,000 gallons, and takes
place over approximately four hours, so that it contributes
12,500 gallons/hour to the effluent. The total flow through
the causeway is about 31,000,000 gallons/day (based on
company figures) or approximately 1,292,000 gallons/hour.
Assuming that a simple dilution effect occurs, the mercury
concentration in the causeway should be about one hundred
times lower than that in the treatment tank drain. The
concentration of mercury in the causeway, particularly
in the second batch discharge, varied over such a wide
range that factors other than simple dilution must be
operative.

The order of magnitude fluctuations in mercury concentrations
both in the treatment tank drain and the causeway suggest
that the mercury is in particulate form. This hypothesis

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is plausible in view of the treatment process used
to remove mercury from the contaminated chlor-alkali
wastes. The one causeway grab sample with a mercury
concentration of 1,500 ug/l could be explained by the
presence in the sample bottle of a single mercuric
sulfide particle with diameter 0.07 cm in the sample
bottle.

The effects of flow dynamics in the causeway and varia-
bility in the composition of the kraft mill effluent
could also contribute to the observed fluctuations in
the concentration of mercury in the causeway.

Dryden Chemicals estimates the amount of mercury in
the discharge by determining the mercury concentration
in a single grab sample from the treatment tank drain,
and multiplying this figure by the volume of water in
the tank. An expected range for the mercury concentration
is established by analyses of the top and bottom of the
treatment tank contents prior to release. In view of
the observed fluctuation in the mercury level in the
treatment tank drain, the analysis of a single grab sample
is not adequate to estimate the mercury discharged to
the Wabigoon River, from the batch treatment process.

The contents of the treatment tank do not represent the
only source of mercury input to the river from the chlor-
alkali plant. The total effluent from this plant, exclusive
of the batch discharges, is approximately 1,500,000 gallons
per day, (based on company figures) through the east
uncontaminated line. Based on the results of seventeen

analyses of the contents of this line over the last two years, the average mercury concentration in this line is 2.8 ug/l, so there is a daily loading of 0.044 lb/day from this source.

In addition, the background concentration of mercury in the Wabigoon River must be considered. Repeated analysis over the past two years has yielded results consistently below 0.1 ug/l for the Wabigoon River upstream of the plant. Using 0.1 ug/l as a high estimate of this background concentration, a contribution of 0.031 lb/day mercury to the gross loading can be calculated due to this input.

Since these are the only known inputs of mercury into the causeway from the chlor-alkali plant, a daily loading can be estimated, and this can be compared with the loading calculated from the average causeway concentration. The average causeway concentration was not calculated as the arithmetic mean of each day's results, since the sampling frequency was higher during the batch discharges, and this would introduce a high bias into the averages. For each day from July 20 to July 25, however, there are results of the causeway mercury concentration for the time periods 0700-1159, 1200-1659, and 1700-2200. Therefore, the results for these time periods for each day were averaged, and the mean of these three averages was used as an estimate of the mean daily mercury concentration in the causeway (a concentration of 1 ug/l was used for the time period 1700-2200 hours on July 25, for which no data was available). The mean daily

causeway concentration was multiplied by 31,000,000
gallons to obtain the daily mercury loading into the
Wabigoon River.

The calculated loading due to the uncontaminated chlor-
alkali lines, background water concentration, and treatment
tank discharges (using both Dryden and MOE estimates of
the concentration of mercury in the treatment tank drain
for each discharge) are listed in Table 3 along with the
observed loadings, the mean mercury concentration in the
causeway, and the daily mercury loadings reported by
Dryden Chemicals.

It is obvious from the discrepancies between the calculated
and observed loadings of mercury into the Wabigoon River
that there are other sources of mercury in the chlor-
alkali/pulp and paper complex aside from the treatment
tank discharges, input from the east uncontaminated line,
and background concentration in the Wabigoon River.

The above conclusions, as well as the unexplained rise
in the concentration of mercury in the causeway from 0.5
to 2.8 ug/l that occurred on July 20 would indicate input
from another source. Possibilities of alternate sources
of mercury input could be an accidental leak of mercury-
containing brine into the cooling water surrounding the
chlor-alkali cells, housekeeping practices such as floor
washing or tank overflow, various inputs of mercury from
the pulp and paper mill, and gradual elimination of
residual mercury remaining either in the sewers or the
causeway.

TABLE 3

CALCULATED MERCURY LOADINGS

Date	Average Mercury Concentration in Causeway (ug/l)	Mercury Loading (lb)[†]			
		Calculation I	Calculation II	Calculation III	Calculation IV
July 20	1.0	0.307	0.075	0.075	0
July 21	1.7	0.518	0.104	0.090	0.01
July 22	0.7	0.213	0.075	0.075	0
July 23	0.7	0.213	0.075	0.075	0
July 24	0.4	0.122	0.075	0.075	0
July 25	59	18	0.181	0.198	0.1
July 25*	3.5	1.07	0.181	0.198	0.1

*   result of 1,500 ug/l neglected

†   Calculation I: this estimate of mercury loading was obtained by multiplying the average causeway concentration by the total daily effluent volume.

    Calculation II: this estimate is the sum of known inputs from the east uncontaminated line, background levels, and the treatment tank discharges using the M.O.E. estimate of the treatment tank mercury concentration (average of four grab samples)

    Calculation III: this estimate is derived in the same manner as calculation II, except that the Dryden Chemicals figure (based on one grab sample) for the mercury concentration in the treatment tank was used.

    Calculation IV: these are the daily loadings reported by Dryden Chemicals.

EVALUATION OF FIELD ANALYSES
FOR MERCURY IN WATER

INTRODUCTION

In view of the need to have a cross-check of analytical data
from the Dryden plant, the samples were analyzed both in the
field and in the Toronto central laboratory. The availability
of a significant population of such duplicate analytical results
for mercury afforded an excellent opportunity to statistically
compare the two sets of results. Since there were essentially
no differences in analytical methodology, reagents used in
the procedure, or instrumentation, any differences in the two
sets of results could probably be attributed to the difference
in the elapsed time between sampling and analysis.

The use of an oxidizing mixture of potassium permanganate and
acid has been recommended as a preservative for mercury in
solution at low concentrations by several analysts (1-3),
and has been used at the Ministry of the Environment laboratories
since 1970. Several studies conducted in the laboratory indicated
that there was no significant loss of mercury from solutions
over 6 days, but the results of field analysis of mercury-
containing waters had not previously been available.

STATISTICAL COMPARISON

Several statistical techniques for the comparison of the two
sets of results (4) were used, and are briefly described below
in non-rigorous terms.

i - Paired t-test:

The t statistic is calculated from the population of differences
between pairs of observations, in this case, the results of
the Dryden and Toronto analyses of the samples. The hypothesis

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tested by the statistic is that there is no significant difference
in the two populations of results, and a high t value results
in the rejection of this hypothesis. The t-statistic is
the ratio of the difference between the population means and
the standard deviation of the population of differences formed
by subtracting the individual pairs of results.

ii - Correlation coefficient:

The correlation coefficient, r, is designed to vary between
+1 and -1 according to the closeness of the relationship between
the two sets of results. A coefficient of +1 indicates a
perfect positive correlation and -1 a perfect negative cor-
relation.

iii - Regression coefficient:

The regression coefficient, b, is the slope of the line of
best fit (least squares) through the points if they are
plotted against each other. Two sets of identical results
would yield a regression coefficient of +1.

RESULTS

The results of the various statistical tests on the analytical
data from the two laboratories are listed in Table 4. The
data was broken down into various ranges of concentration to
evaluate possible bias in one of the sets of results at
different mercury levels.

The t-test indicated that there was no significant difference
between the two sets of results, and this was confirmed by the
high correlation coefficients. The regression coefficients

TABLE 4

Concentration Range (ug/l)	N	Mean of Dryden Results	Mean of Toronto Results	Correlation Coefficient, r	Regression Coefficient, b	t*
0-33,000	91	441	459	0.999	1.060	0.037 (1.982)
0-100	85	4.11	3.83	0.967	0.927	0.168 (1.988)
0-10	79	1.43	1.34	0.982	0.892	0.353 (1.989)
0-1	42	0.48	0.49	0.947	0.975	0.192 (2.018)
0.0.5	23	0.29	0.29	0.890	0.843	0.183 (2.069)

*   The figure in parentheses is the value for t at which there would be

    95% confidence that the observed difference in the means is significant.

indicated a tendency for the Toronto results to be lower than the Dryden results at the low concentrations, but the trend was not statistically significant.

The percentage difference in the pairs of results was plotted against the difference in the elapsed time between the two analyses, but no trend was evident (see Figure 6). Figure 7 is a plot of the two sets of results in the range 0 to 5 ug/l, and demonstrates the high degree of correlation.

DISCUSSION

Regardless of the range of the mercury concentration in the samples considered, there was no significant difference in the two sets of analytical data. This indicates that the mixture of nitric acid and potassium permanganate presently used for the preservation of aqueous samples for mercury analysis is adequate at least nine days.

In addition to the duplicate analyses in Toronto and Dryden eight of the samples were analyzed in Winnipeg. Agreement between the Dryden and Winnipeg results was quite good (see Appendix I). The fact that the results of the analyses in Winnipeg were slightly higher than those obtained in Dryden may be attributed to the fact that no reagent blank subtraction was used in calculating the Winnipeg results, because samples of the necessary chemicals were not available.

Analytical accuracy was evaluated by the analysis of an NBS mercury standard solution of 1.18 ug/l. The results of 10 such analyses averaged 1.22 ug/l, or 103.4% of the reported

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FIGURE 6

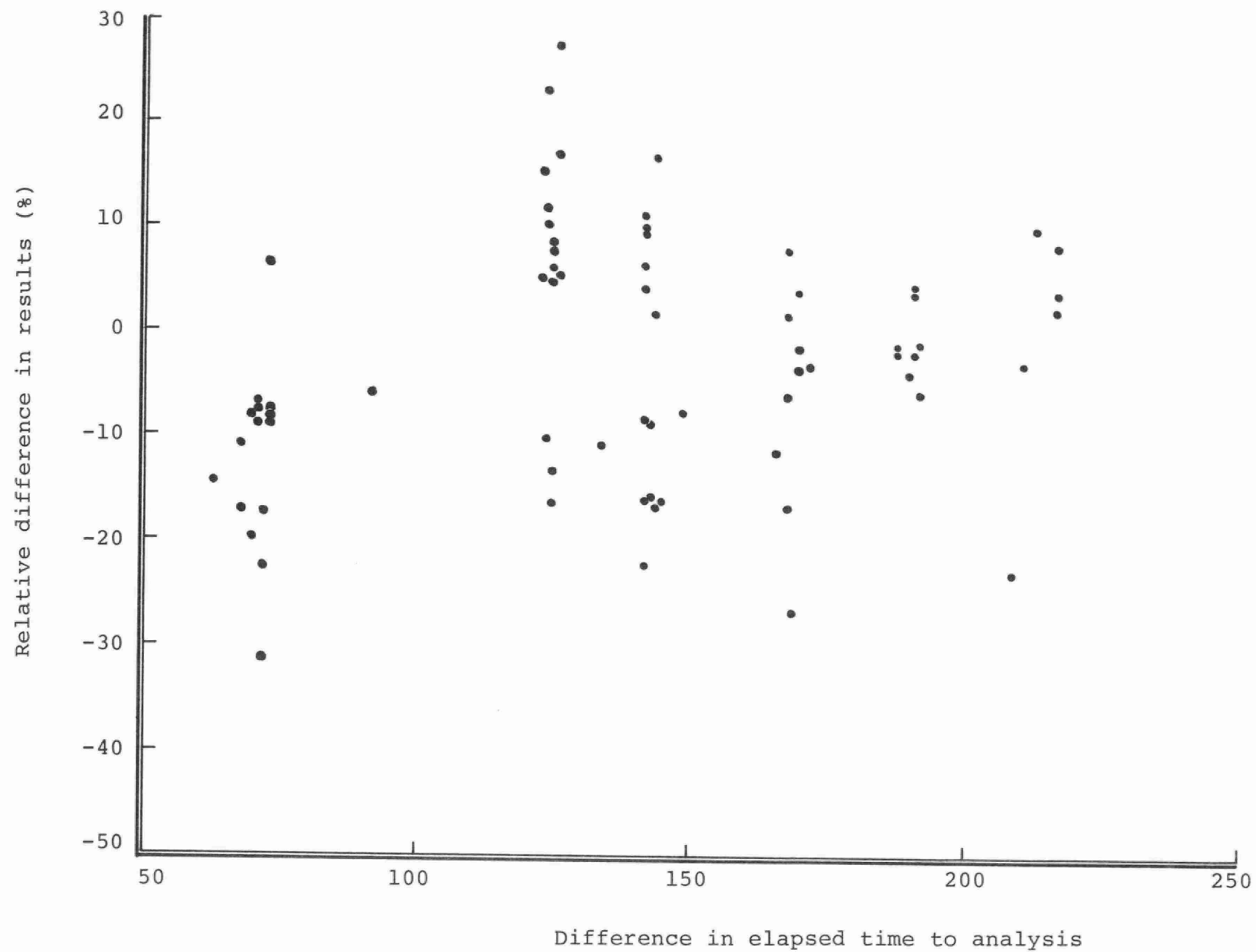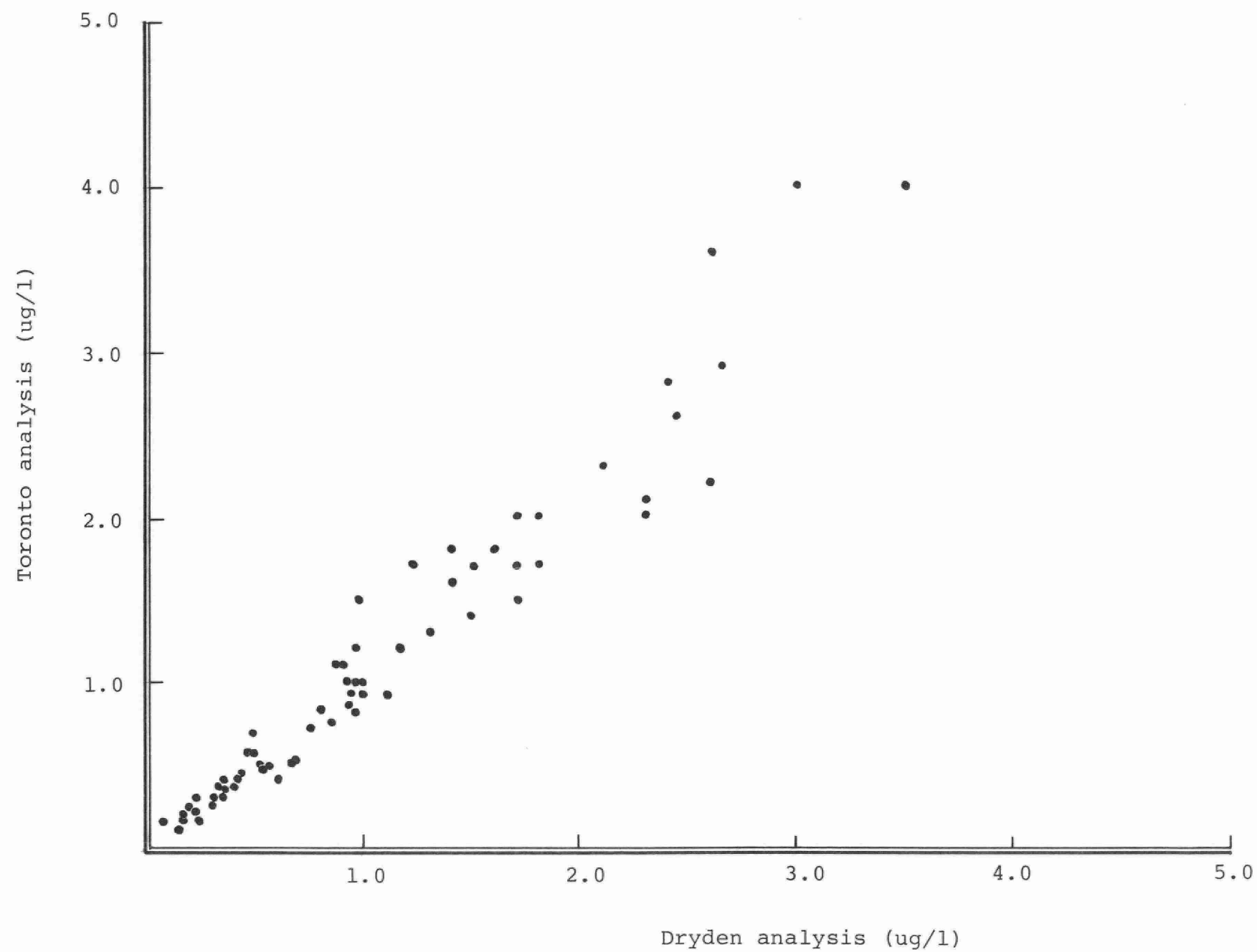Difference in elapsed time to analysis

FIGURE 7

value. Reproducibility of the analyses averaged 3.5% in the Dryden laboratory and 3% in the Toronto laboratory, based on duplicate and triplicate analysis of some of the samples.

CONCLUSIONS

1) Every 4 to 5 days, Dryden Chemicals Limited releases
    35,000 to 65,000 gallons of effluent treated chemically
    to remove the mercury. The results of analyses of this
    treated effluent were used in estimating the total release
    of 0.03 to 0.11 lb of mercury due to these discharges.

2) Dryden Chemicals also releases 1.5 million gallons of
    untreated water per day. The average concentration of
    mercury in this effluent was 2.8 ug/l, so a loading of
    0.03 lb per day can be attributed to this input.

3) Based on repeated analyses of the total effluent below
    the Dryden Chemicals and Reed Paper Company plants, an
    estimated daily loading was 0.1 to 1 lb of mercury per
    day.

4) There is a large discrepancy between mercury loadings
    calculated from the chlor-alkali plant losses, and the
    loading observed in the combined chlor-alkali and pulp
    and paper mill effluent.

5) The concentration of mercury fluctuated over a wide
    range in the combined chlor-alkali and pulp and paper
    mill effluent. Individual samples, therefore, are not
    adequate for the proper assessment of the daily mercury
    loading. To obtain a realistic estimate, composite samples
    are mandatory.

6) The preservation method for the analysis of mercury in
    waste water samples was proven to be effective for at
    least nine days.

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1) S. H. Omang, "Mercury in Natural Waters by Atomic Absorption Spectrophotometry" Anal. Chim. Acta, <u>57</u> 415 (1971).

2) V. I. Muscat, T. J. Vickers, "Determination of Nano-gram Quantities of Mercury by the Reduction-aeration method and Atomic Fluorescence Spectrophotometry", Anal. Chim. Acta, <u>57</u>, 23 (1971).

3) T. Y. Toribara, C. P. Shields, L. Doval, "Behaviour of Dilute Solutions of Mercury" Talanta, <u>17</u>, 1025 (1970).

4) G. W. Snedecor "Statistical Methods" Iowa State College Press, 1956.

APPENDIX I

ANALYTICAL RESULTS

DATE	SAMPLING LOCATION	TIME	MERCURY CONCENTRATION (ug/l)	
			DRYDEN	TORONTO
July 18	causeway	0830	–	0.7
"	causeway	1130	0.4	0.4
"	causeway composite (Jul.17)	–	1.1	0.4
"	sewer 10 compositor	1510	0.4	0.4
"	sewer 11	1520	0.3	0.3
"	sewer 13 compositor	1530	2.3	2.1
July 19	causeway composite (Jul.18)	–	0.5	0.6
"	causeway	1010	0.3	0.3
July 20	causeway composite (Jul.19)	–	0.6	0.7
"	causeway	1015	0.5	0.6
"	causeway compositor	1015	0.9	1.0
"	sewer 13 compositor	–	1.7	1.7
"	causeway	1215	0.7	0.7
"	causeway	1415	0.8	0.9
"	causeway	1615	0.8	0.8
"	causeway	1815	1.7	1.2
"	causeway	2020	1.8	1.9*
"	causeway	2215	2.8	2.6*
"	Lake Wabigoon	2230	0.2	0.3*
July 21	causeway	0730	1.8	2.1*
"	causeway compositor	0930	1.9	2.5*
"	causeway	0930	1.6	1.9*
"	causeway	1030	2.0	2.8*
"	treatment tank drain	1045	23	32 *
"	treatment tank drain bucket	1045	31,000	33,000
"	causeway	1100	2.9	2.7
"	causeway	1130	1.0	1.0
"	causeway	1200	1.2	1.2
"	treatment tank drain	1215	57	60
"	causeway	1230	1.4	1.5

*   analysis performed at Freshwater Institute, Winnipeg, Manitoba.   /.....

APPENDIX I continued.....

| DATE | SAMPLING LOCATION | TIME | MERCURY CONCENTRATION (ug/l) | |
			DRYDEN	TORONTO
July 21	sewer 13	1240	2.6	2.4
"	causeway	1300	1.6	1.4
"	treatment tank drain	1315	210	190
"	causeway	1330	1.7	1.5
"	sewer 13	1340	3.6	2.6
"	causeway	1400	1.5	1.0
"	treatment tank drain	1415	17	13
"	causeway	1430	1.8	1.6
"	sewer 13	1440	4.0	3.5
"	causeway	1500	2.0	1.8
"	treatment tank drain bucket	1515	55	31
"	causeway	1530	1.7	1.5
"	sewer 13	1540	4.0	3.0
"	causeway	1600	1.8	1.4
"	causeway	1800	2.0	1.7
"	causeway	2045	0.9	0.7
"	causeway	2200	1.1	0.9
July 22	causeway	0900	1.3	1.3
"	causeway composite (Jul.21)	-	1.3	1.1
"	causeway	1200	0.4	0.4
"	causeway	1500	0.4	0.4
July 23	causeway	1630	0.3	0.3
"	causeway	0930	1.0	1.0
"	causeway	1230	0.7	0.5
"	causeway	1530	0.6	0.5
"	causeway	1900	0.4	0.3
July 24	Wabigoon River	0950	0.04	0.1
"	causeway composite (Jul.23)	-	0.4	0.4
"	causeway	1000	0.6	0.5
"	sewer 13	1010	1.1	0.9
"	top of 90,000 gal.treatment tank	1120	9.6	9.8
"	service water	1120	0.2	0.1

APPENDIX I continued.....

DATE	SAMPLING LOCATION	TIME	MERCURY CONCENTRATION (ug/l)	
			DRYDEN	TORONTO
July 24	service water	1130	0.5	0.7
"	chlorate ejector water	1130	0.5	0.7
"	west uncontaminated line	1140	1.6	1.4
"	east uncontaminated line	1140	1.2	1.0
"	Wabigoon River at STP	1315	0.3	0.2
"	causeway	1530	0.3	0.3
"	causeway	1830	0.2	0.2
"	causeway	2345	0.4	0.3
July 25	causeway	0730	0.2	0.3
"	sewer 13	0740	0.4	0.4
"	sewer 10	0745	0.2	0.3
"	sewer 11	0750	0.1	0.1
"	causeway	800	0.2	0.2
"	treatment tank drain	0805	390	450
"	causeway	0830	9.8	7.7
"	treatment tank drain	0845	130	140
"	treatment tank drain bucket	0845	670	550
"	sewer 13	0855	0.9	0.9
"	causeway	0900	0.8	0.8
"	causeway	0930	0.4	0.6
"	treatment tank drain	0945	37	43
"	sewer 13	0955	2.8	2.4
"	causeway	1000	0.9	1.1
"	causeway	1030	0.5	0.7
"	treatment tank drain	1045	54	58
"	sewer 13	1055	1.0	0.9
"	causeway	1100	0.5	0.6
"	sewer 10	1105	0.5	0.5
"	sewer 11	1110	0.2	0.2
"	causeway	1130	–	1,500
"	treatment tank drain bucket	1145	7,400	7,200

APPENDIX I continued......

| DATE | SAMPLING LOCATION | TIME | MERCURY CONCENTRATION (ug/l) | |
			DRYDEN	TORONTO
July 25	sewer 13	1155	5.4	5.7
"	causeway	1200	16	15
"	causeway	1230	5.8	5.1
"	sewer 13	1255	1.5	1.7
"	causeway	1300	2.0	2.3
"	sewer 10	1305	1.7	1.8
"	sewer 11	1310	0.2	0.2
"	causeway at outfall pipe	1320	2.1	2.3
"	causeway 20' below outfall pipe	1320	2.2	2.6
"	Wabigoon River at STP	1630	-	1.0

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